Multi-Spacecraft Coherent Doppler and Winging for Interplanetary Navigation

Vincent M. Pollmeier[1]

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA

Abstract

Future interplanetary mission concepts are increasingly focusing on multi-spacecraft missions and on mall sample return missions which may involve the rendezvous between a spacecraft which brings a sample from the surface of a solar system body and a spacecraft which will return the sample to the Earth. These types of missions place tight requirements on **the** knowledge of the relative positions of the spacecraft. Historically spacecraft positions have been determind by the use of radio metric data (Doppler and range) between the spacecraft and terrestrial receiving stations. The use of two independent spacecraft to ground radio links for multi-spacecraft missions is inefficient in its usage of limited ground resources and frequently does not provide an adequate determination of the relative spacecraft positions. Use of radio metric data originating on one spacecraft which is then received, processed, and either telemetered to the Earth or processed onboard can provide a more direct measurement of spacecraft relative positions. Such a system was carried aboard the *Mars Observer* spacecraft as part of ***the*** Mars Balloon Relay package that was to track Russian Mars landers. However, these systems place a tight requirements on the stability of onboard frequency standards on both spacecraft and on the precision of the data extraction hardware on the spacecraft,

An alternative is to extend the coherent ground to spacecraft link through one spacecraft to the other and then to the ground or back through the first spacecraft and to the ground receiver. Although initially appearing to complicate the separation of the dynamics of the two spacecraft, this paper will show that in actual application, judicious selection of spacecraft transponder frequency ratios and the use of coherent Doppler and ranging and the derived observable, DRVID (Differenced Range vs. Integrated Doppler) can allow for the generation of observable equations which are dominated by the spacecraft to spacecraft link. This is due to the fact that although transponder frequency ratios affect the Doppler observable they do not affect the ranging observable. Consequently, these ratios can be chosen such that the effect on a DRVID observable of a path length change over one link can be maximized, while the effect of other links can be minimized. Numerical analysis shows that this provides significantly improved navigation capability, over telemetered systems and multiple Earth to spacecraft links, while decreasing the demands on the spacecraft hardware capabilities.

[1] Technical Manager, Navigation Systems Section